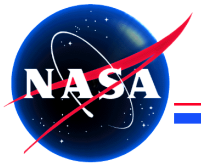

Initial IKONOS Modulation Transfer Function Compensation (MTFC) Evaluation

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March 19-21, 2001

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Contributors

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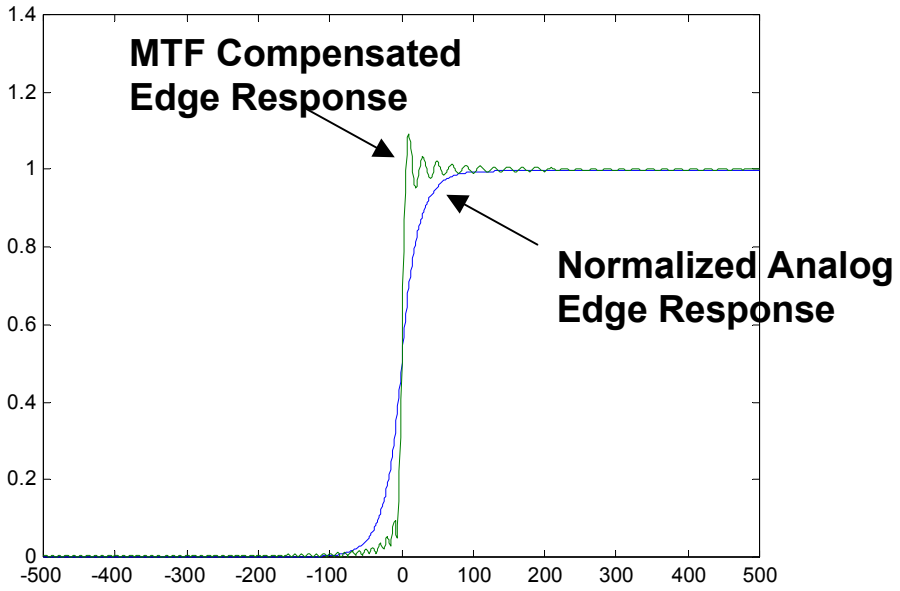
Introduction

- **NASA Scientific Data Purchase (SDP) orders imagery with MTFC ON to stay consistent with commercial product offerings**
- **SDP IKONOS data specifications were developed before SI products were fully defined**
  - MTFC is not mentioned in SDP contract
  - NASA discovered products were MTFC through examination of metafiles
- **Objectives**
  - Examine radiometric differences between MTFC ON and MTF OFF for panchromatic and multispectral imagery (MS)
  - Understand impact on various work such as vicarious radiometric calibrations and sensor inter-comparison (L7)
  - Examine MTFC effects on SNR

Background

- **MTFC is an edge sharpening technique used to partially restore image degradation to imperfections in the imaging process**
  - Historically used in CRT displays and by the intelligence community
  - Implemented in analog electronics or digitally

Simulated Edge Response



MTFC sharpening edges but can produce overshoot and ringing

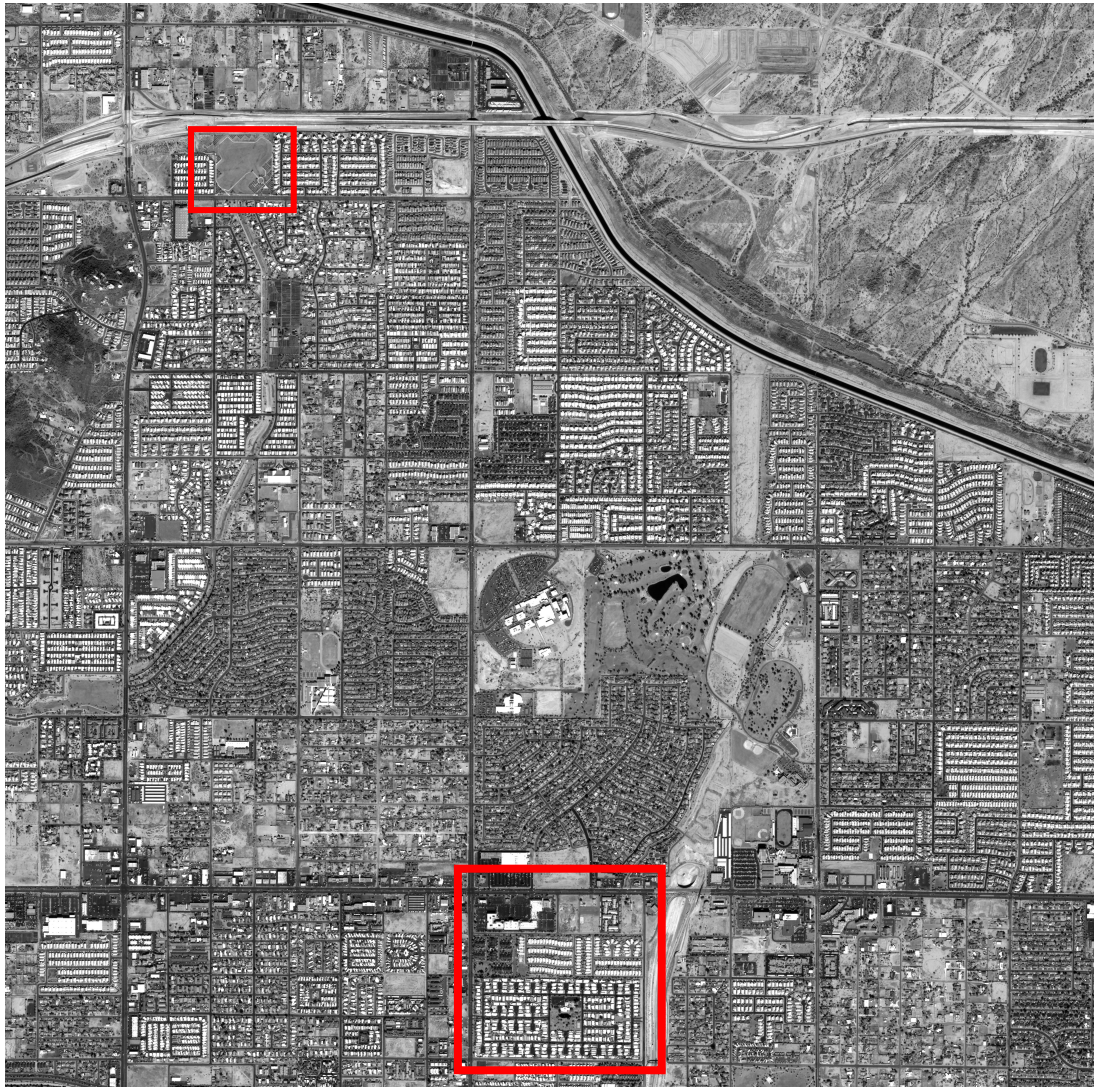
Approach

- **Perform Visual Inspection on MTFC ON and MTFC OFF Imagery**
  - Panchromatic and MS
  - Difference Imagery
- **Examine the effects of Space Imaging MTFC kernel on simulated images**
  - Examine Edge Response
  - Examine Aliasing Effects
- **Perform quantitative analysis on MTFC ON and MTFC OFF Imagery**
  - Histograms
  - Scatter plots
  - RMS and peak differences
  - Estimate MTFC

Visual Inspection

Phoenix PO ID# 33667

- 1 Meter Panchromatic
- October 12, 1999
- MTFC ON
- Satellite Elevation Angle 60.7°



Phoenix MTFC ON/MTFC OFF Pan Comparison

Stennis Space Center

1m Panchromatic Imagery Acquired October 12, 1999

MTFC ON

MTFC OFF

Phoenix MTFC ON/MTFC OFF RGB Comparison

Stennis Space Center

4m Multispectral Imagery Acquired October 12, 1999

MTFC ON

MTFC OFF

Phoenix MS Blue Band Difference Image

Stennis Space Center

Abs (MTFC ON - MTFC OFF)

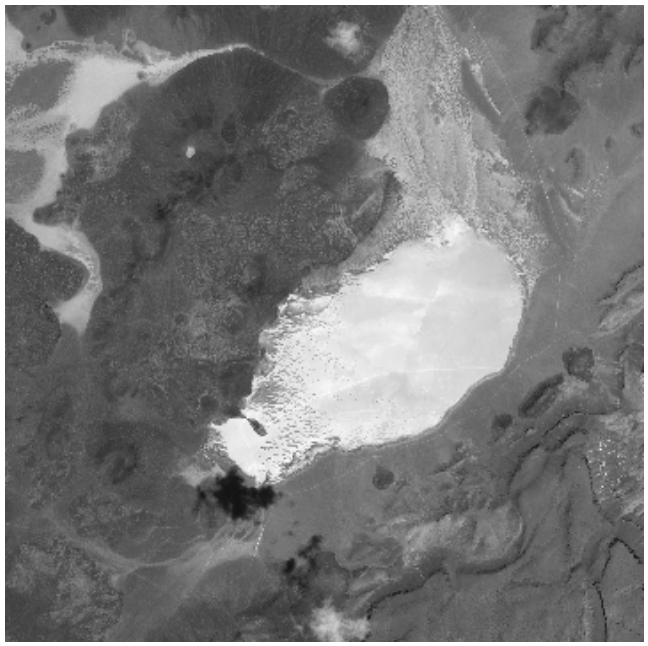
Smallest Effects in uniform areas

Largest Effects in areas with sharp features

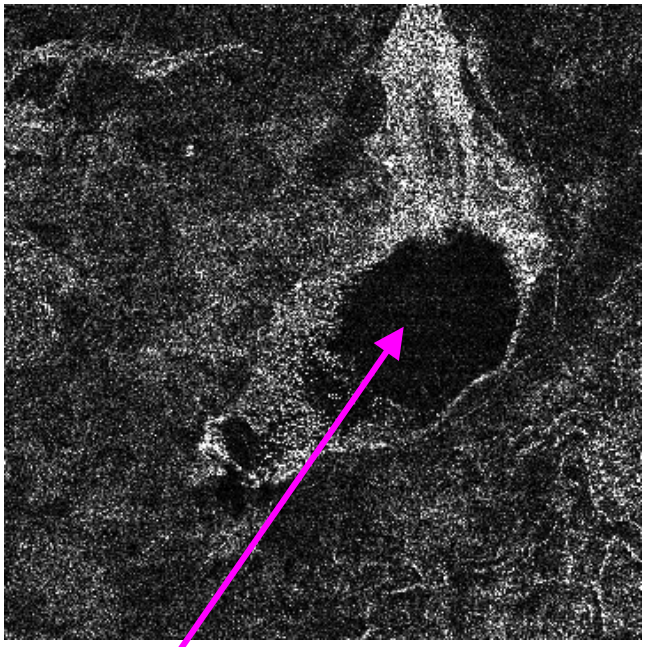
Lunar Lake MS NIR Band Difference Image

Stennis Space Center

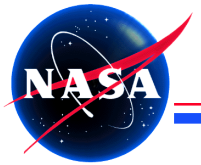
New Lunar Lake MS Near IR MTFC On Image



New Lunar Lake MS Near IR Absolute Value Image of MTFC On - MTFC Off

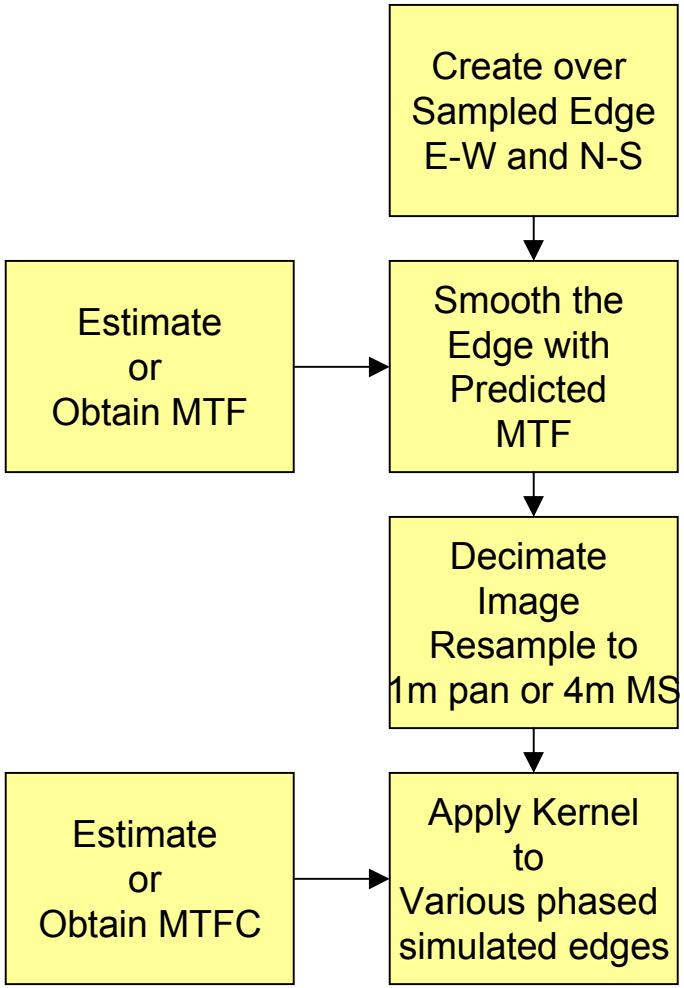


There is not a noticeable difference between MTFC ON and MTFC OFF for highly uniform scenes like Lunar Lake



SI MTFC Kernel Analysis

Simulation Approach



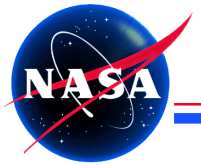
Oversampled
GSD $_{pan}$ = 0.125m
GSD $_{MS}$ = 0.5m

MTF $_{pan}$ @ Nyquist = 0.1
MTF $_{MS}$ @ Nyquist = 0.24

Sensor Sampling
GSD $_{pan}$ = 1m
GSD $_{MS}$ = 4m

Use estimated MTFC or SI provided kernel

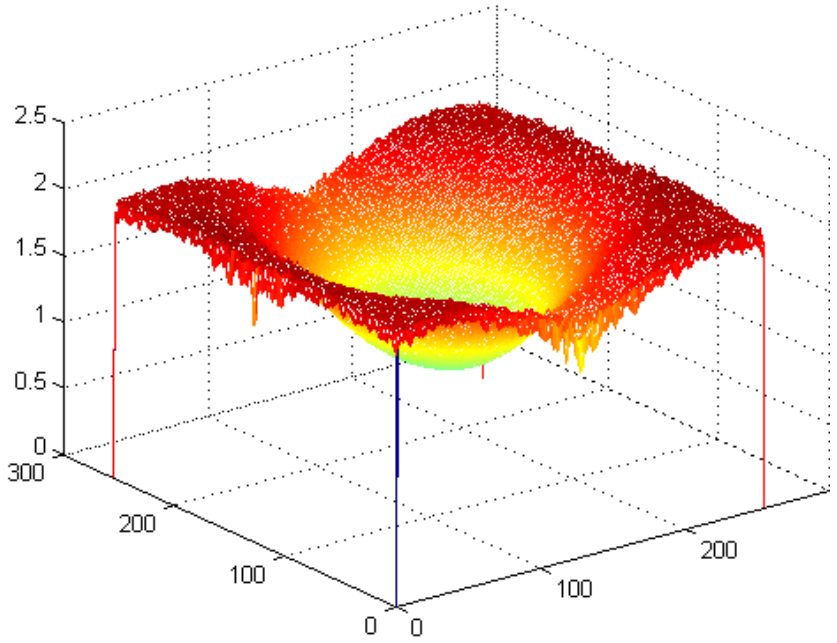
MTFC Estimation



MTFC Estimation Approach

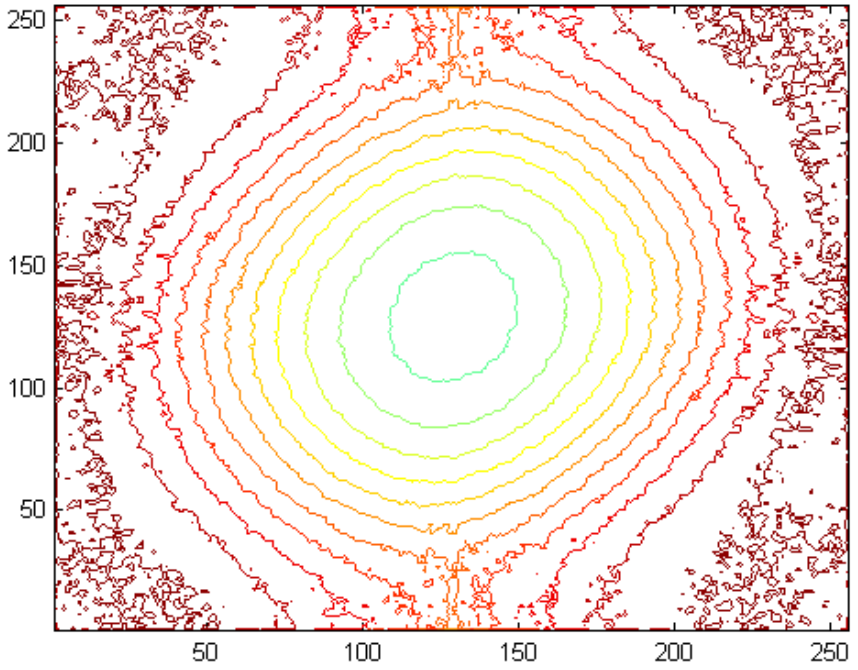
1. Segment image into blocks
2. DFT MTFC ON image blocks
3. DFT MTFC OFF image blocks
4. Ratio MTFC ON DFT to MTFC OFF DFT
5. Smooth MTFC to provide estimate
6. Use MTFC estimate to develop inverse filter function and attempt restoration

Estimated MS NIR MTFC



Estimated MTFC Function for the MS NIR Image

Stronger Compensation in Row Direction

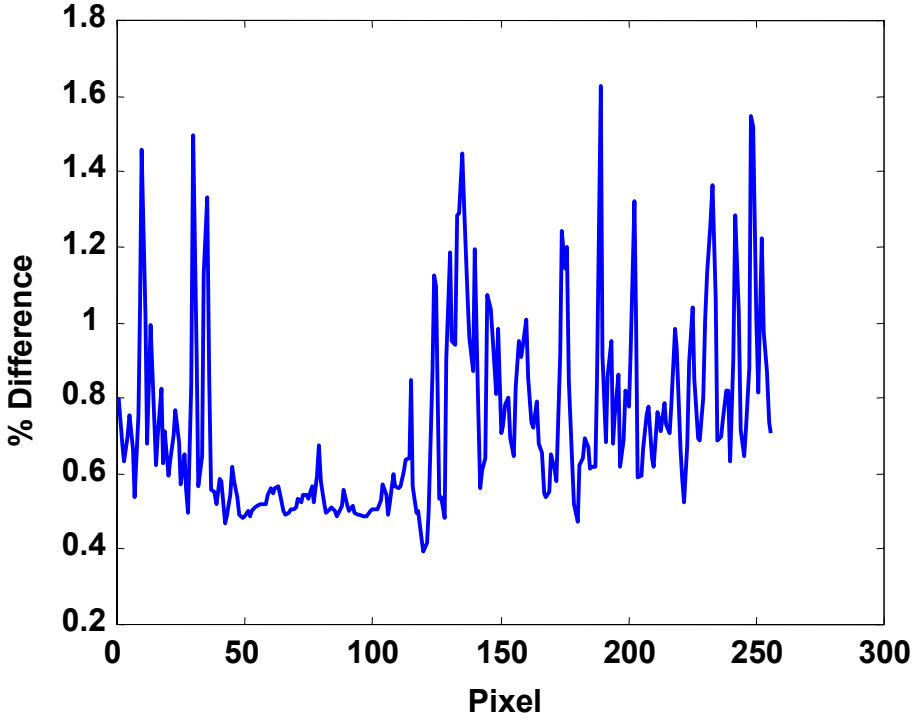


MS NIR MTFC Contour

Rotation appears to be geometric correction effect

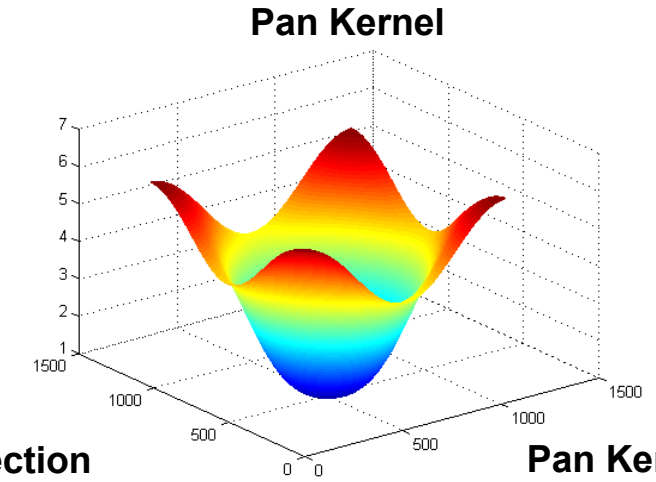
Difference between Restored and MTFC OFF NIR Image

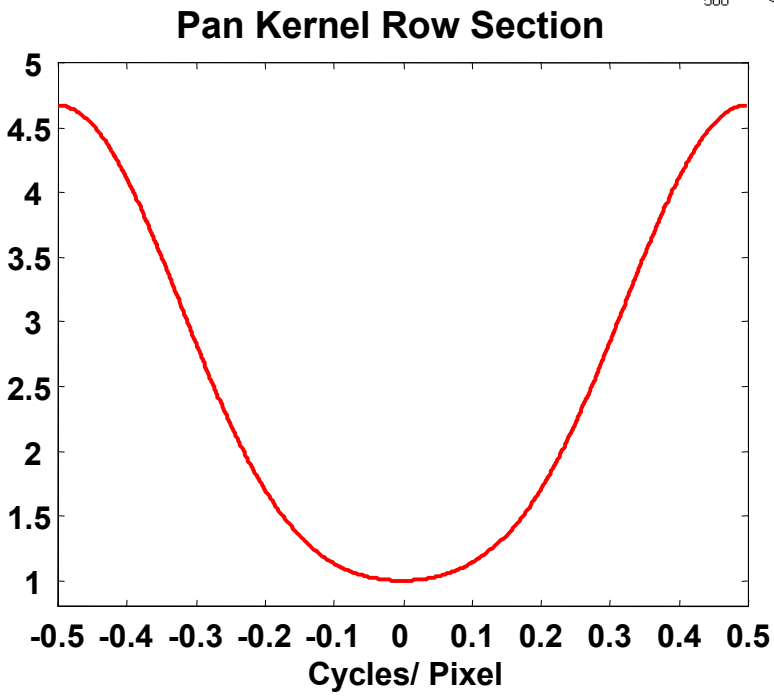
% Difference Between Restored and Original Cross-section Image

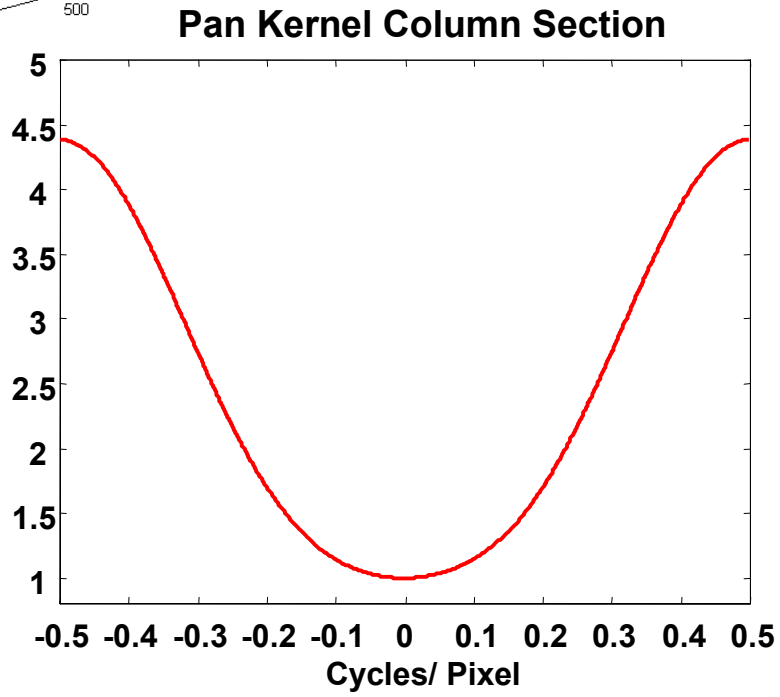


Due to noisy estimate performed analysis with SI provided kernel

Pan Band MTFC



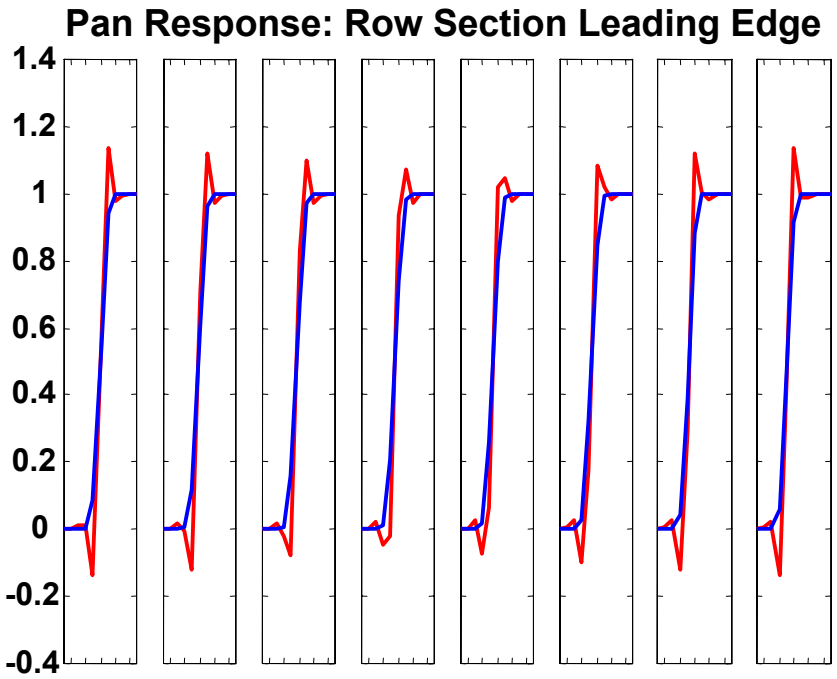


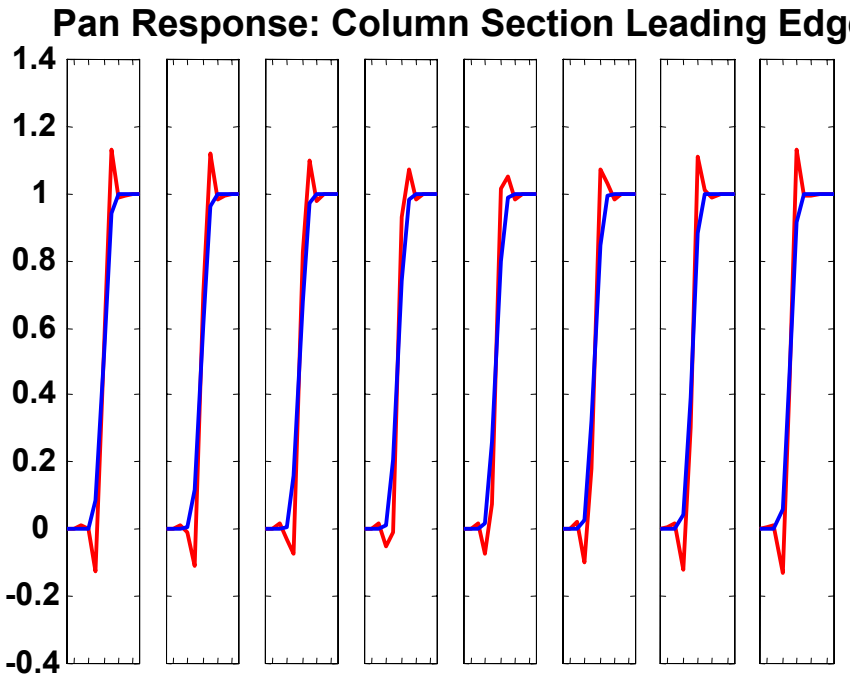


Row MTFC slightly stronger

Pan MTFC Edge Response with Phasing Effects

Stennis Space Center

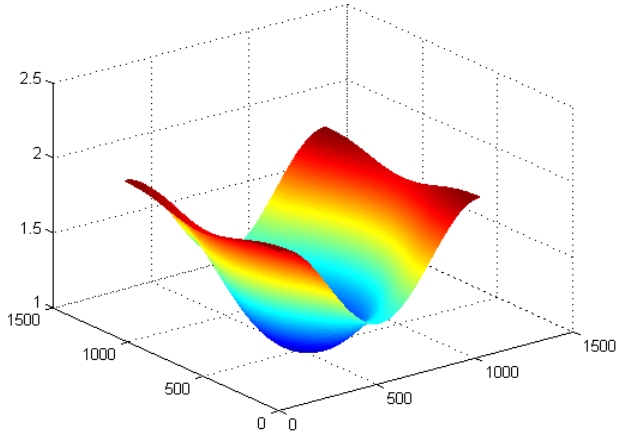




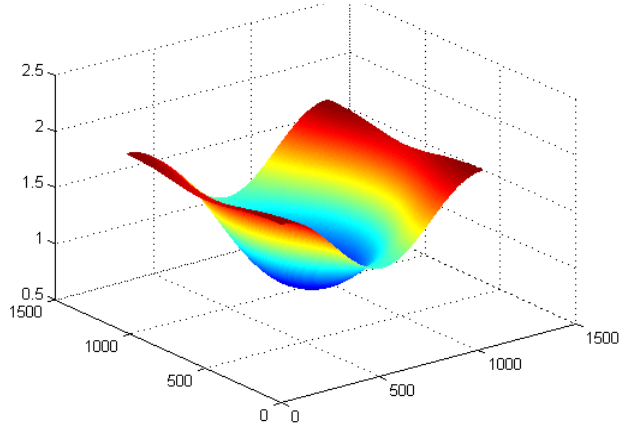
MTFC @ Nyquist assumed to be 0.1 with 1/8 pixel steps

MTFC MS Kernels

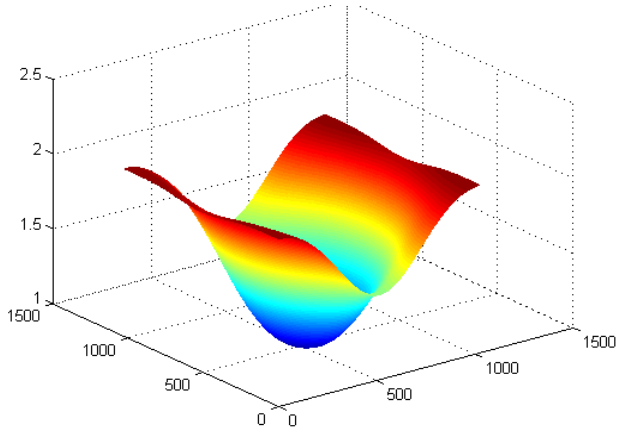
Blue Kernel



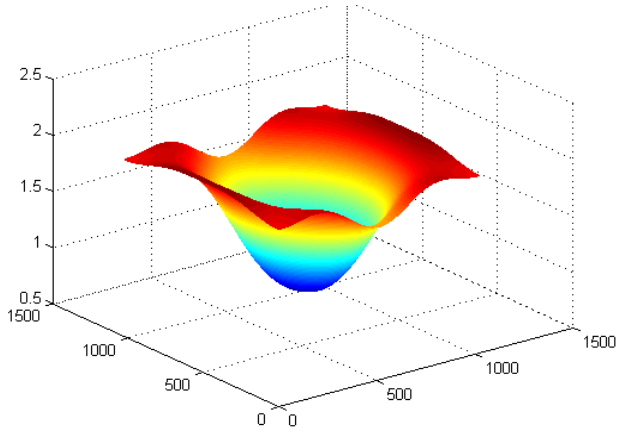
Green Kernel



Red Kernel

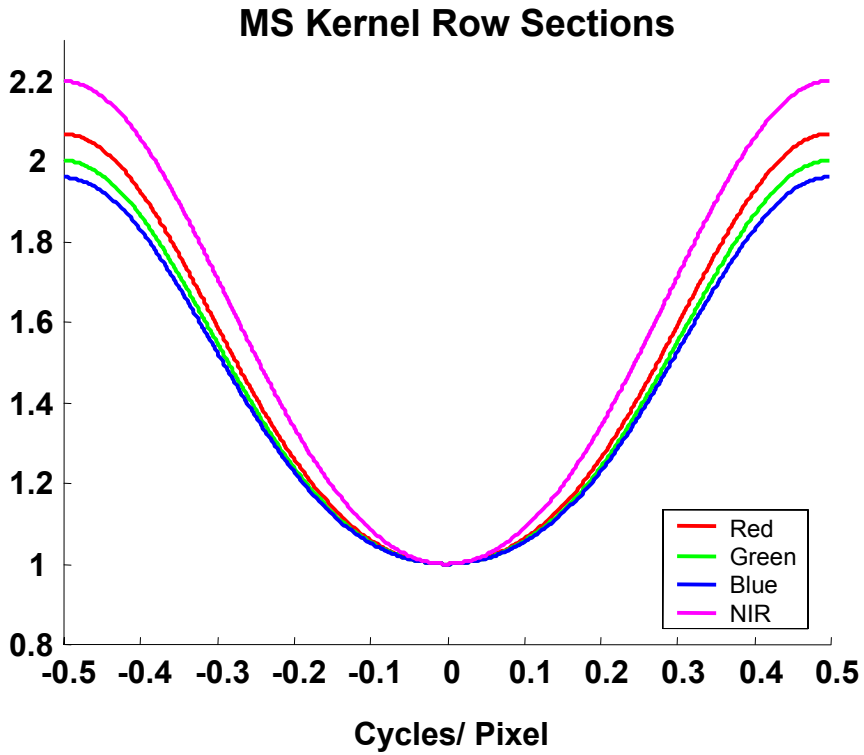


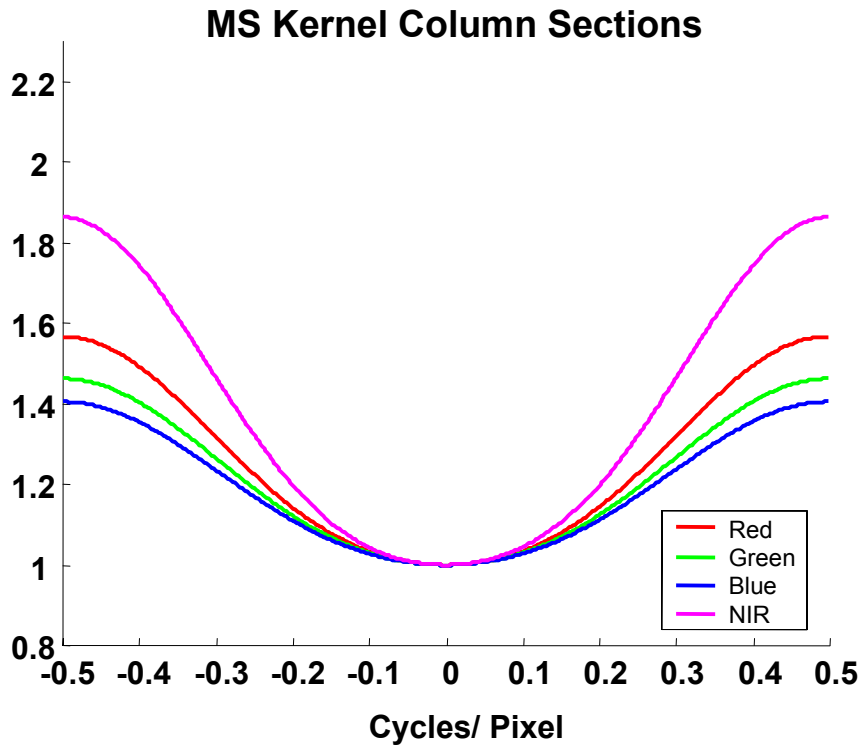
NIR Kernel



Row MTFC is stronger than column MTFC

MTFC MS Band Comparisons



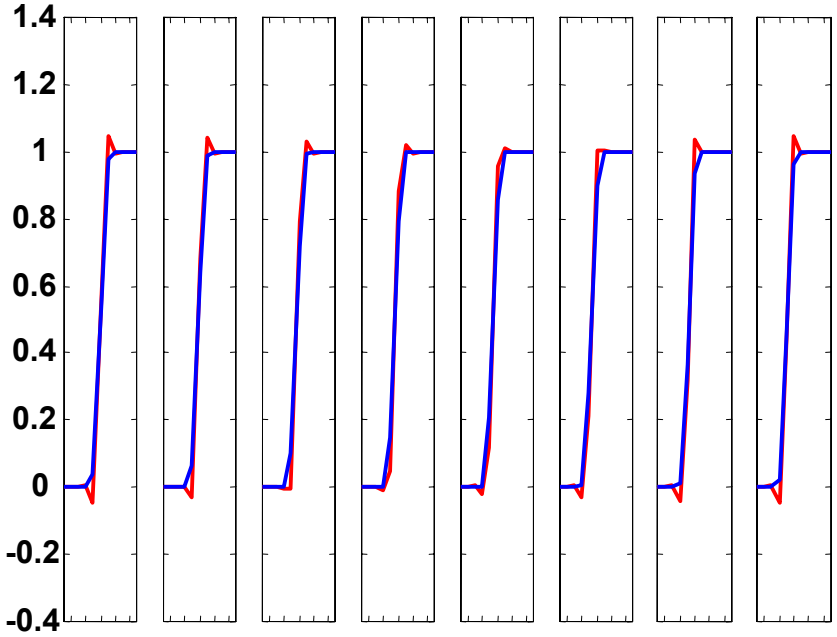


MTFC compensations increases with increasing wavelength

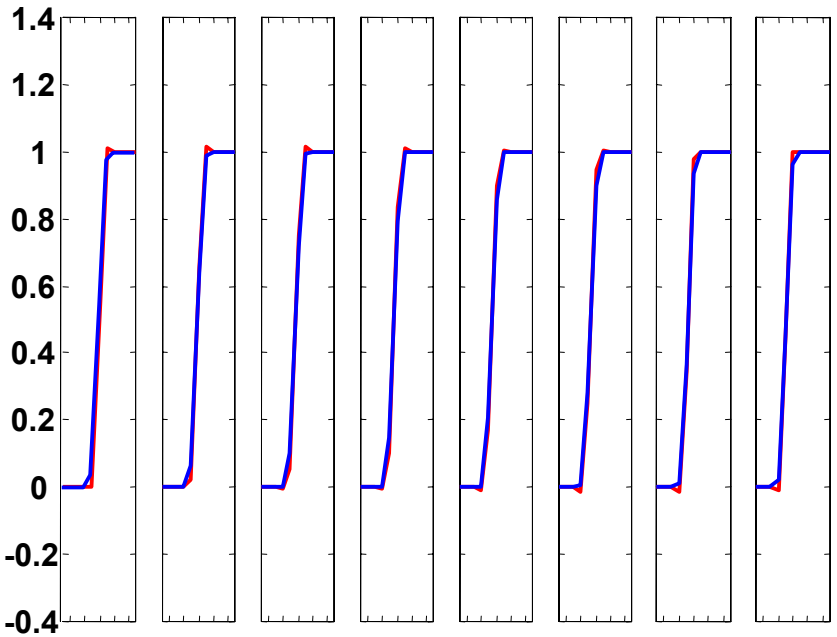
Blue Band MTFC Edge Response with Phasing Edge

Stennis Space Center

Blue Response: Row Section Leading Edge



Blue Response: Column Section Leading Edge

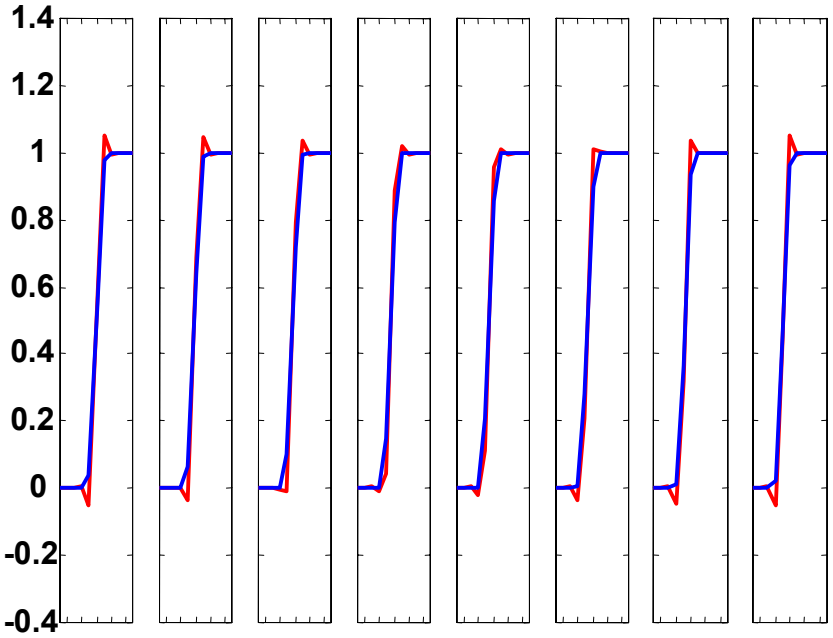


Overshoot more pronounce in row direction

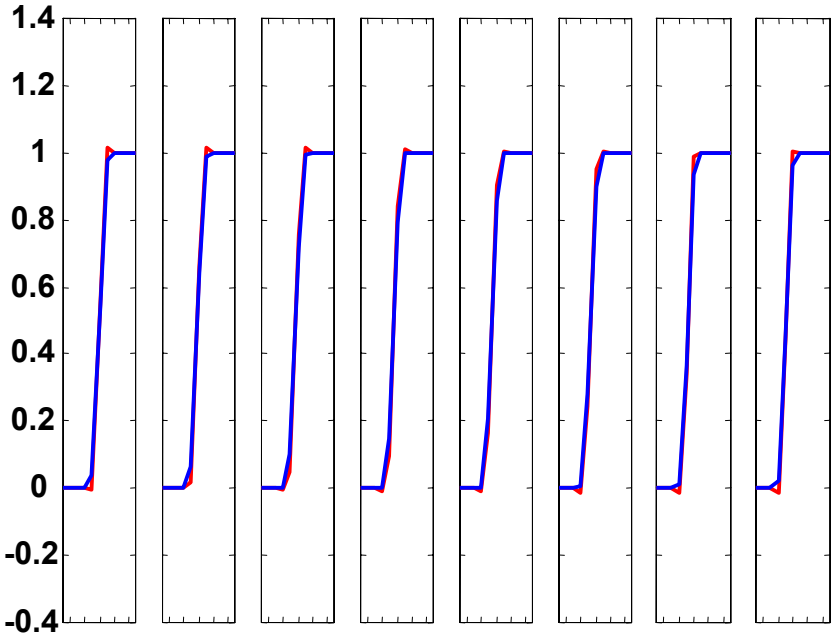
Green Band MTFC Edge Response with Phasing

Stennis Space Center

Green Response: Row Section Leading Edge



Green Response: Column Section Leading Edge

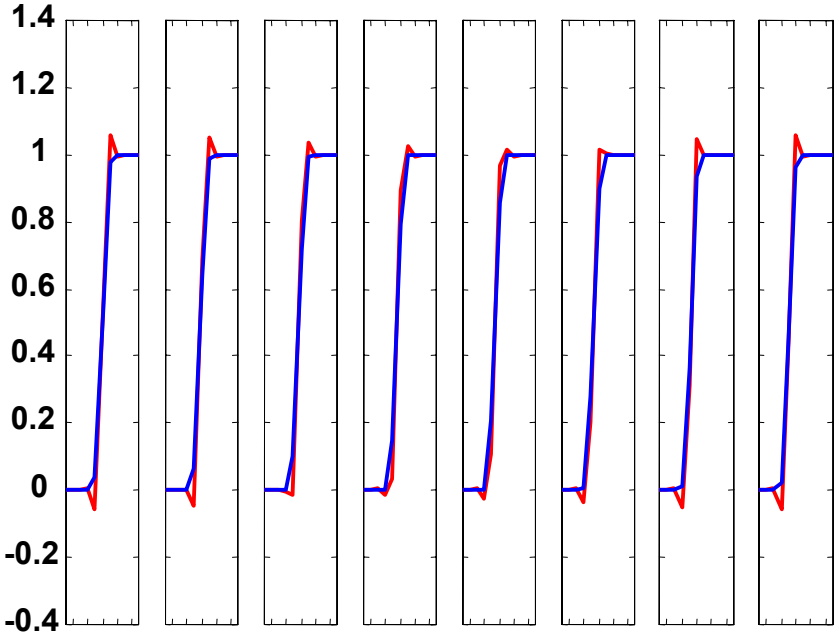


Overshoot more pronounce in row direction

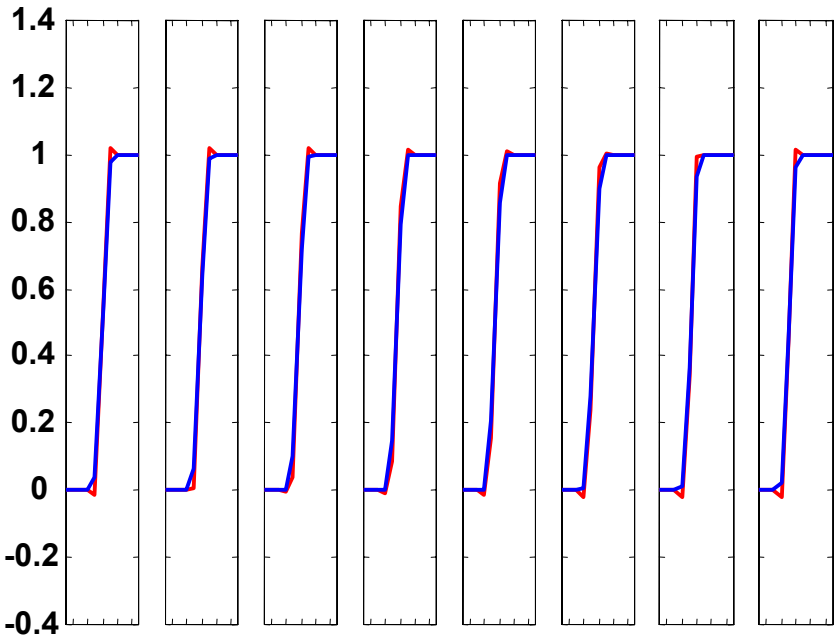
Red Band MTFC Edge Response with Phasing

Stennis Space Center

Red Response: Row Section Leading Edge



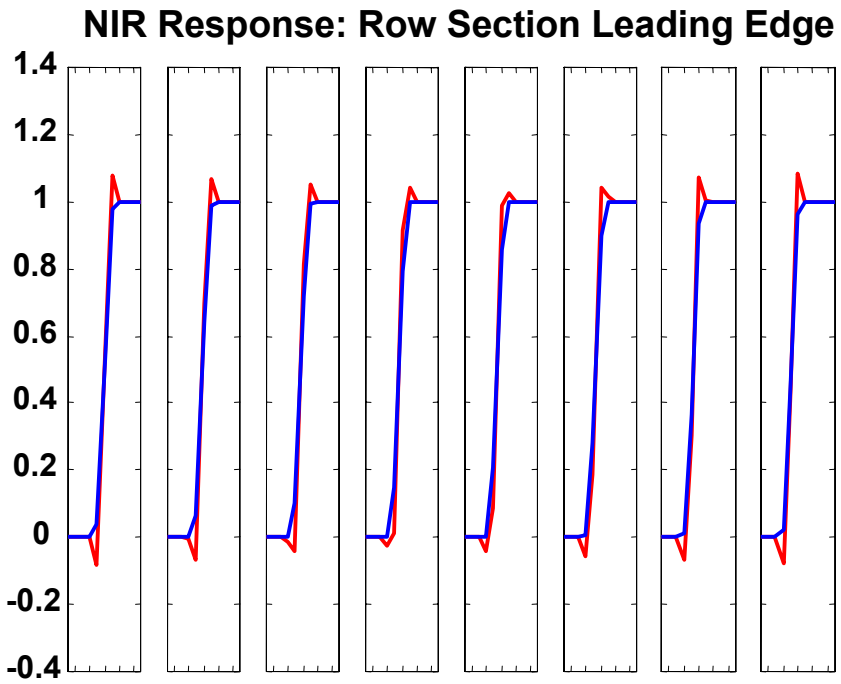
Red Response: Column Section Leading Edge

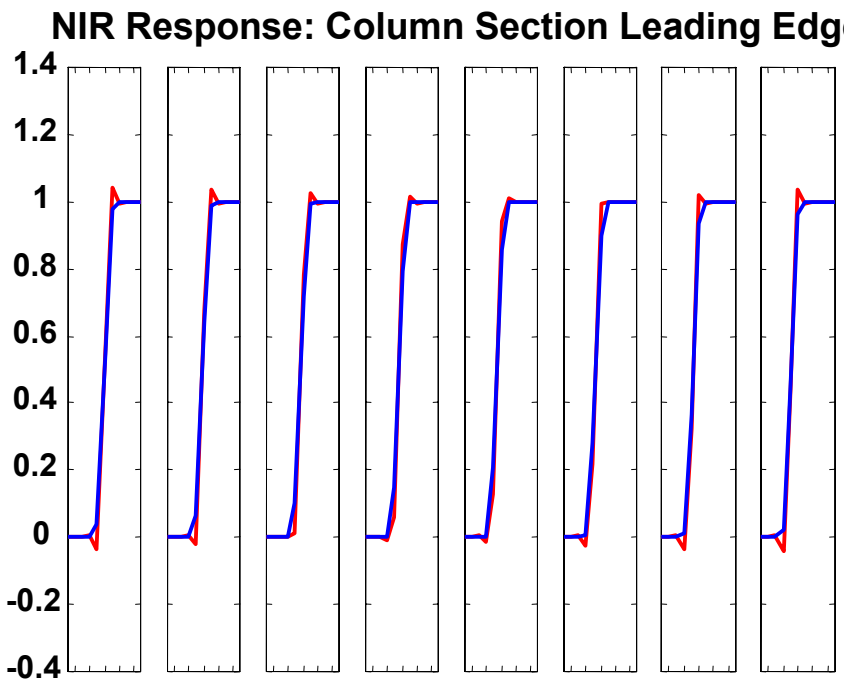


Overshoot more pronounce in row direction

NIR Band MTFC Edge Response with Phasing

Stennis Space Center





NIR is more symmetrical than other bands

Quantitative Analysis

- Intercomparisons
- Scatter plots
- Histograms

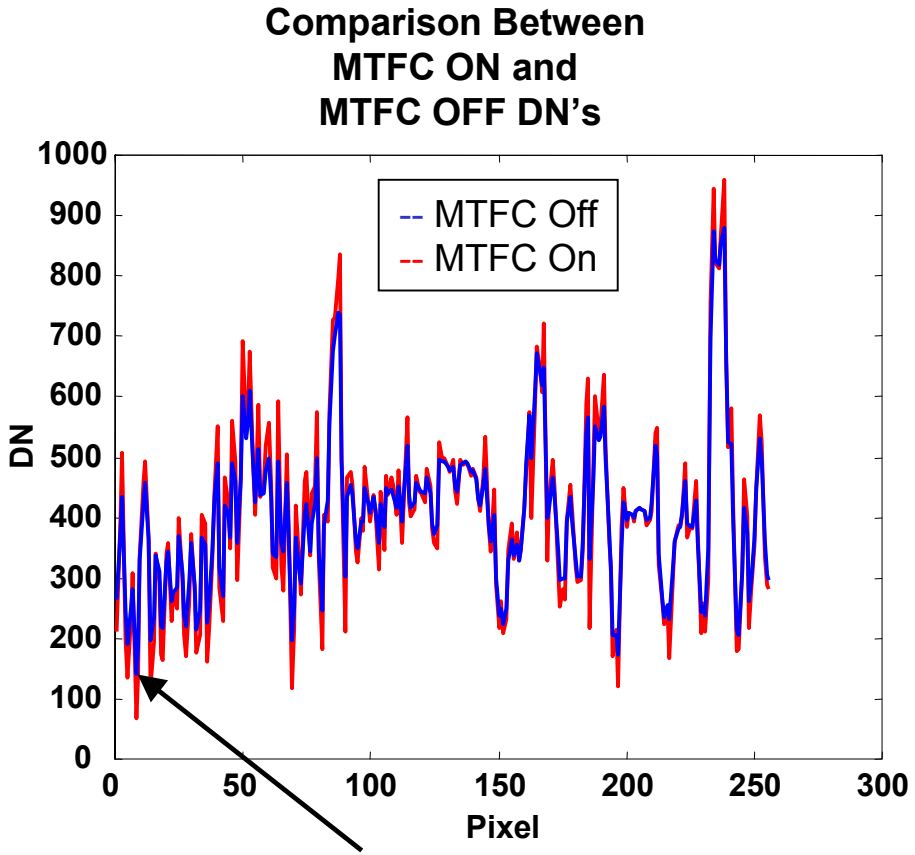
MTFC ON/OFF Imagery Under Analysis

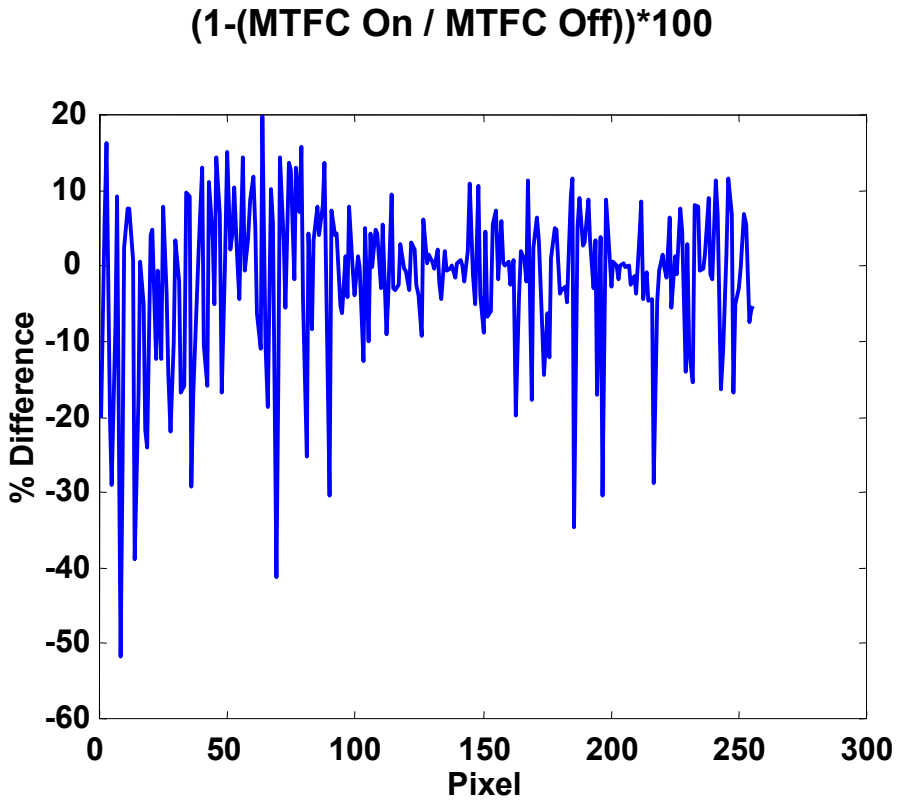
Stennis Space Center

SITE	MTFC ON PO ID #	MTFC OFF PO ID #	Purpose
Phoenix	33667	33668	Urban site with many edges
Tucson	48561	51367	Urban site with many edges
Lunar Lake	39390	53143	Radiometric site

Most analysis has been done on Phoenix Imagery

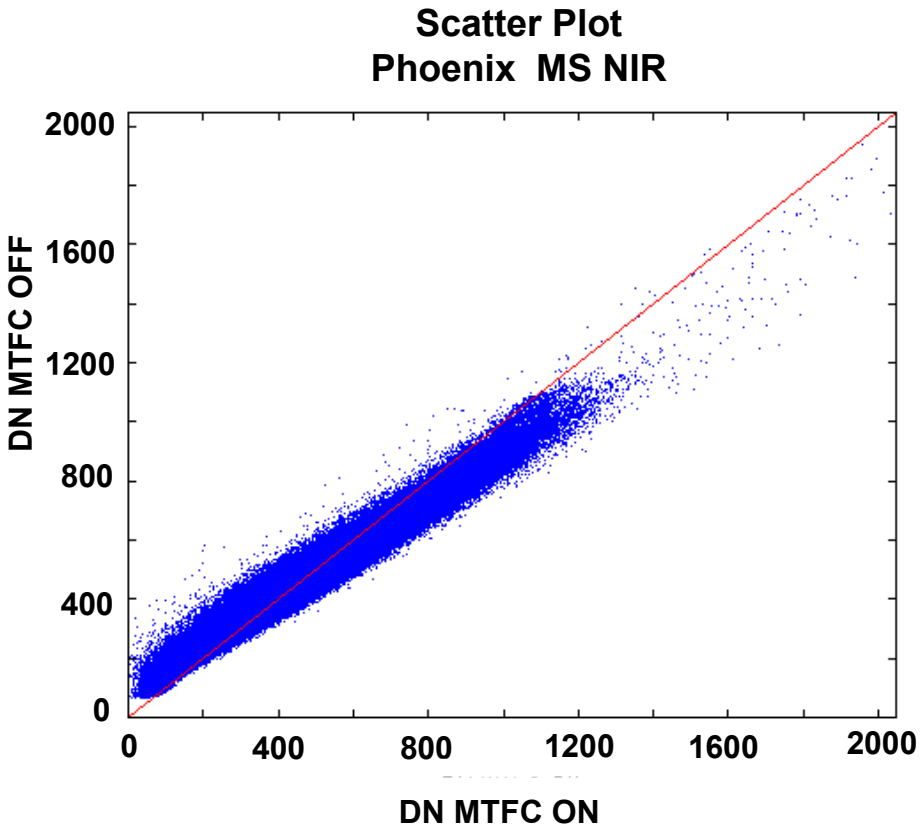
Example NIR Band Phoenix Cross Section

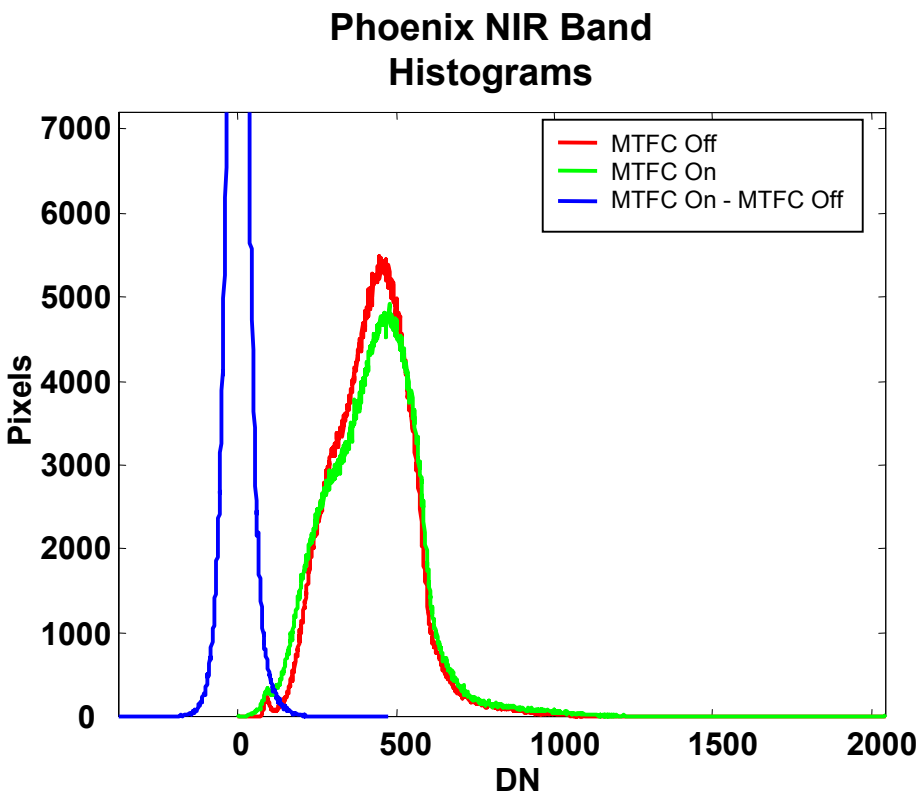




Regions with both large positive and negative swings can produce significant changes

Phoenix Near IR Band





Some outliners are produced but mean of image is unchanged

Phoenix Multispectral Statistics Summary

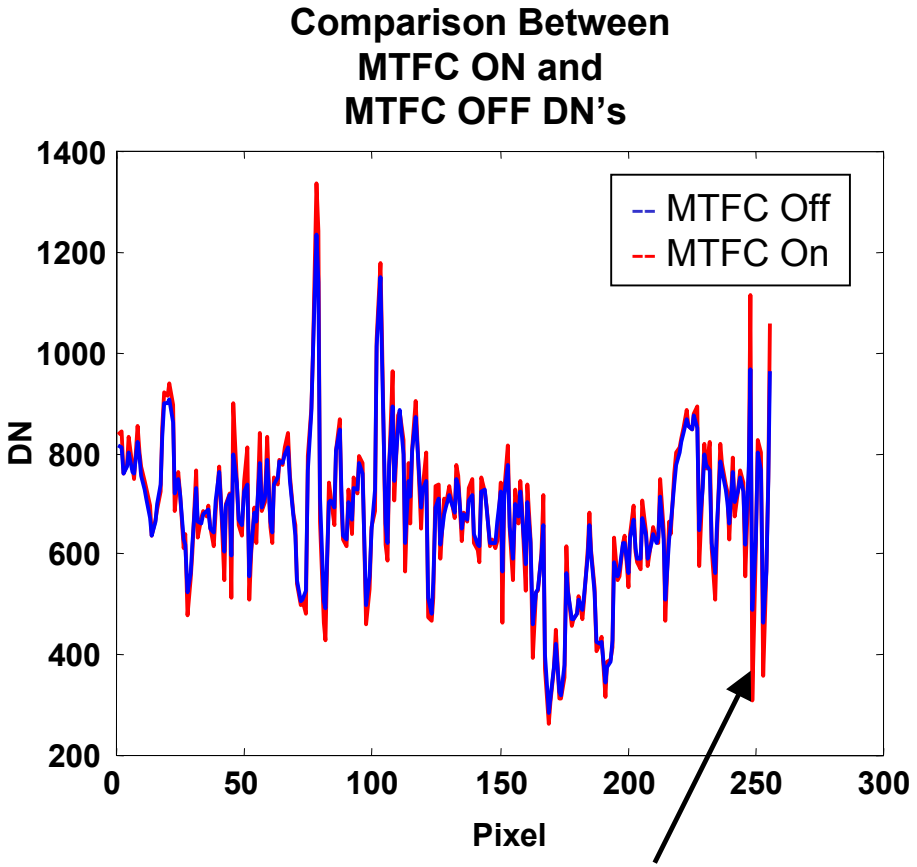
Stennis Space Center

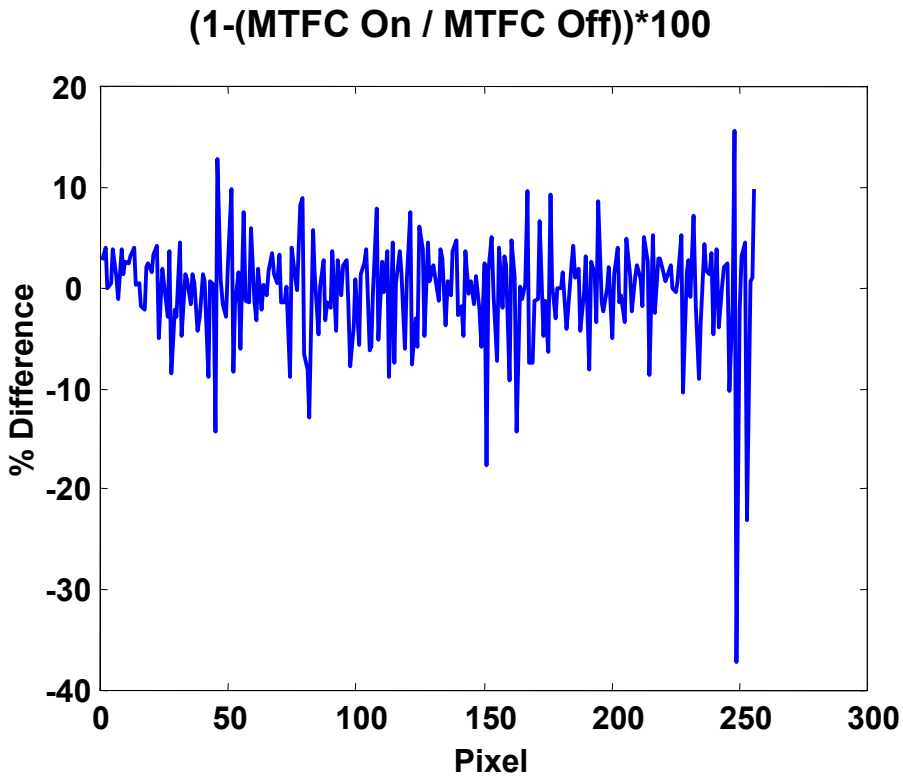
	Blue		Green		Red		NIR	
	MTFC OFF	MTFC ON	MTFC OFF	MTFC ON	MTFC OFF	MTFC ON	MTFC OFF	MTFC ON
Mean	328.3	328.3	412.5	412.5	397.8	397.8	426.9	426.8
Standard Dev	89.46	97.89	133.45	147.29	146.0	161.5	126.2	145.84
Min	153	0	135	0	83	0	65	0
Max	2047	2047	2047	2047	2047	2047	2047	2047
Max Diff	425		444		454		427	
Min Diff	-327		-307		-327		-378	
RMS Difference %	4.7		5.9		7.0		7.6	

Phoenix Panchromatic Statistics

Statistic	Panchromatic MTFC OFF	Panchromatic MTFC ON
Mean	598.2	598.2
Standard Dev	183.6	205.2
Min	149	0
Max	1983	2047
Max Diff	844	
Min Diff	-781	
RMS Difference %	8.5	

Example NIR Band Tucson Cross Section

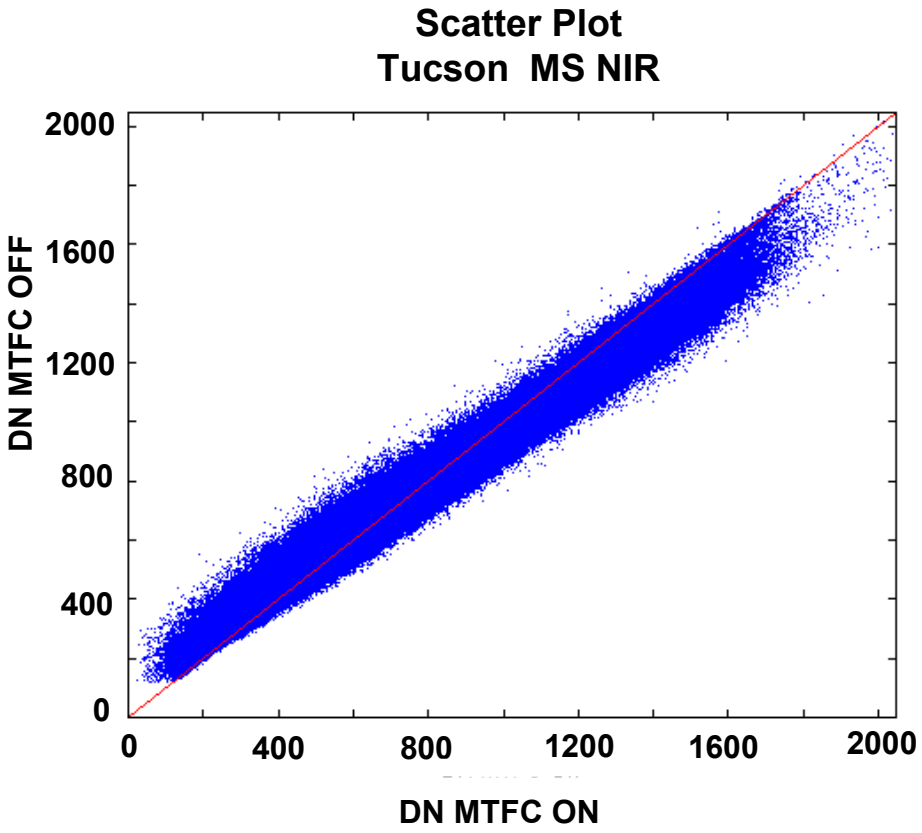


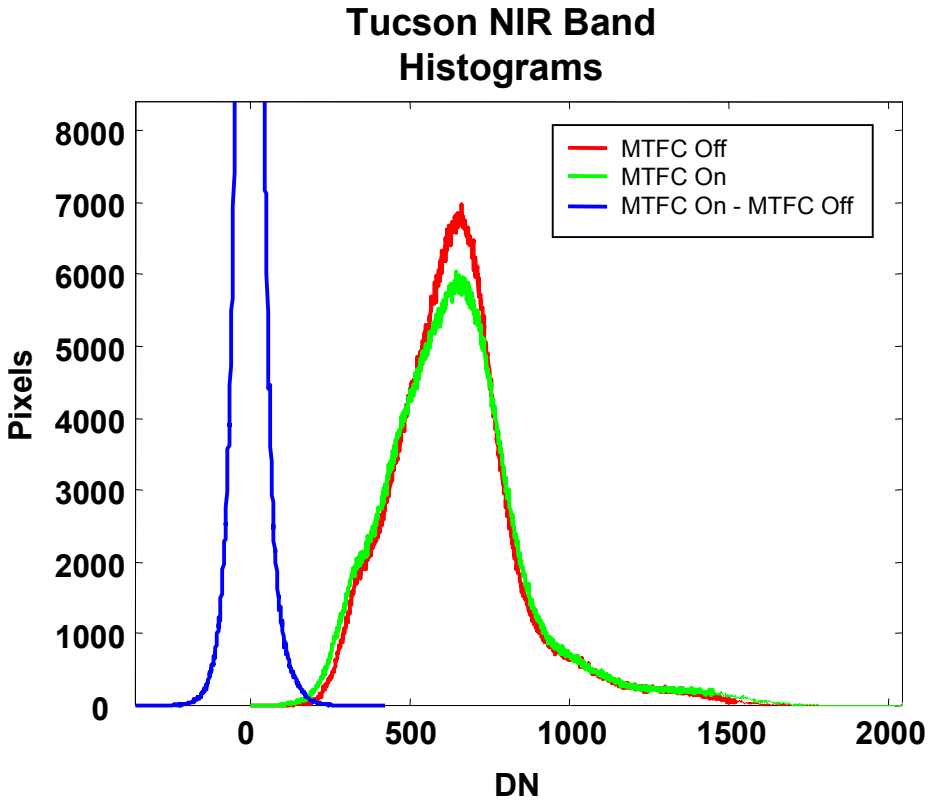


Regions with both large positive and negative swings can produce significant changes

Tucson Near IR Band

New Tucson MS Near IR Histograms

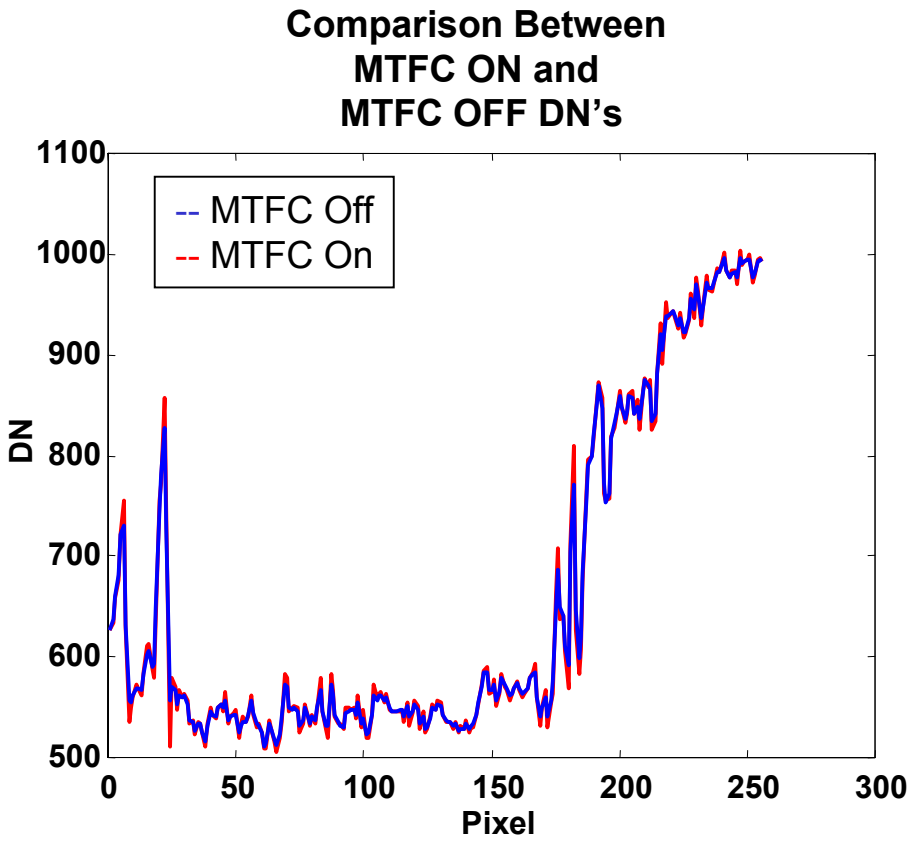


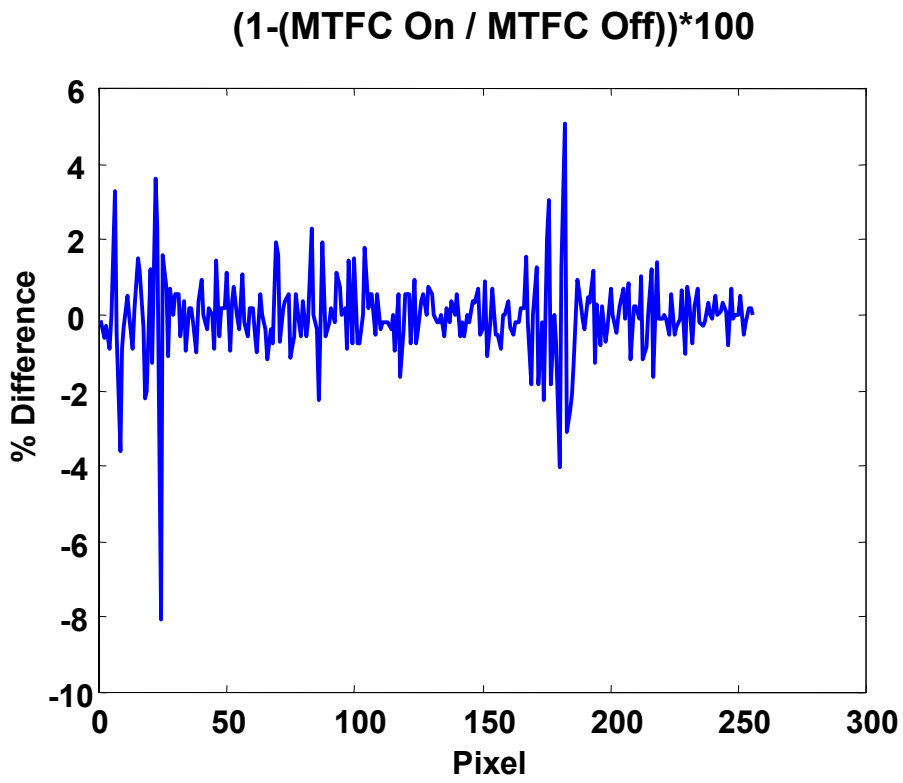


Some outliners are produced but mean of image is unchanged

Example NIR Band Lunar Lake Cross Section

Stennis Space Center

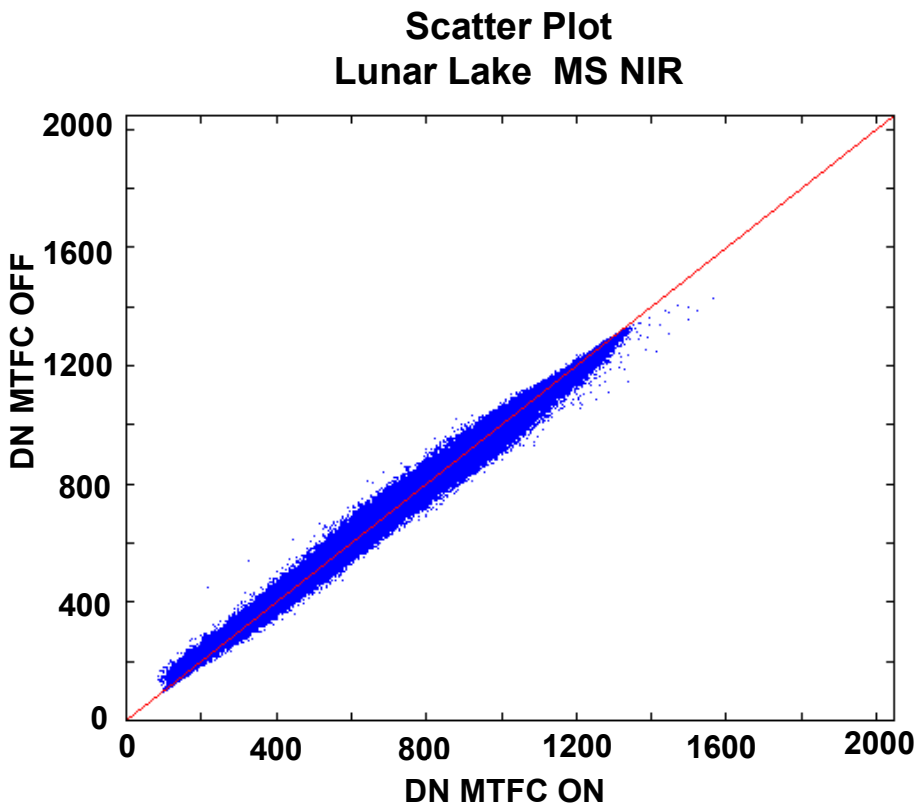


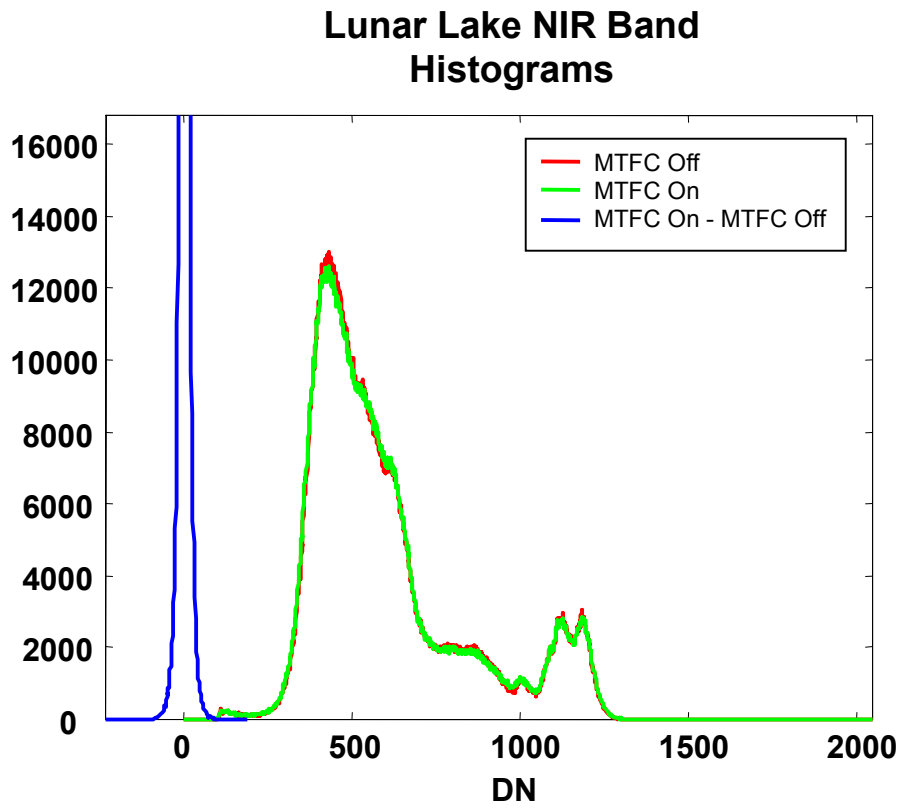


Highly uniform scenes do not show significant change between MTFC ON and MTFC OFF

Lunar Lake MS NIR Band Histograms

Stennis Space Center





The histograms for MTFC ON and MTFC OFF do not show significant change

Lunar Lake Multispectral Statistics Summary

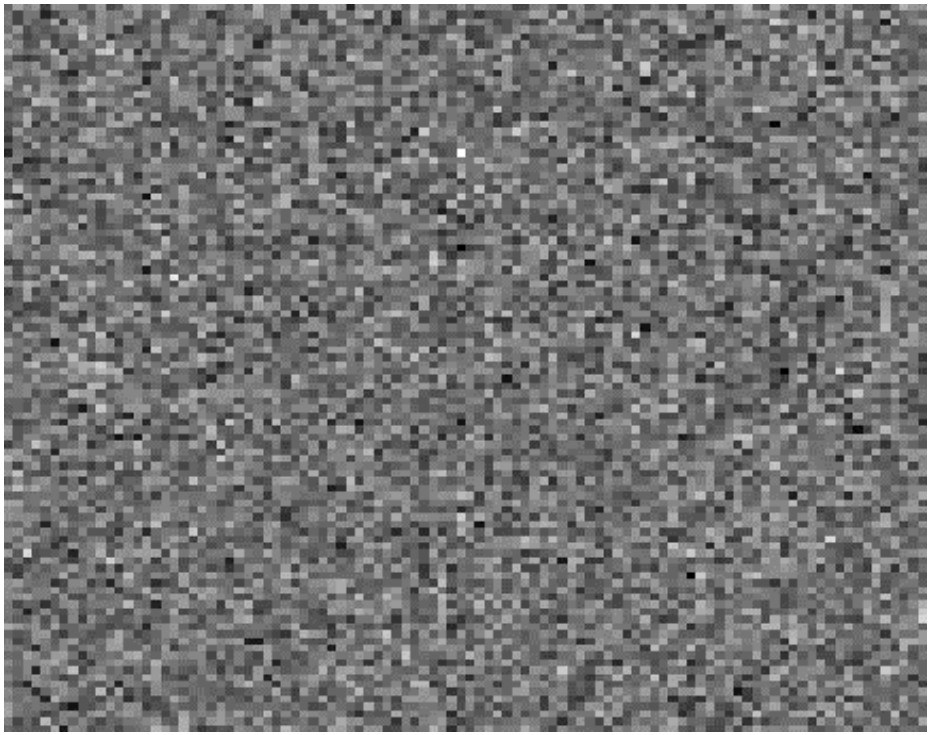
Stennis Space Center

	Blue		Green		Red		NIR	
	MTFC OFF	**MTFC ON**	**MTFC OFF**	**MTFC ON**	**MTFC OFF**	**MTFC ON**	**MTFC OFF**	**MTFC ON**
Mean	762.8	764.4	1089.3	1090.7	1104.4	1105.4	1020.7	1021.6
Standard Dev	8.13	11.37	12.76	17.71	13.12	17.64	13.14	17.91
Min	741	739	1058	1051	1070	1067	990	984
Max	782	800	1118	1138	1140	1157	1051	1067
Max Diff	31		60		49		56	
Min Diff	-26		-42		-38		-42	
RMS Difference %	1.5		1.6		1.7		1.8	

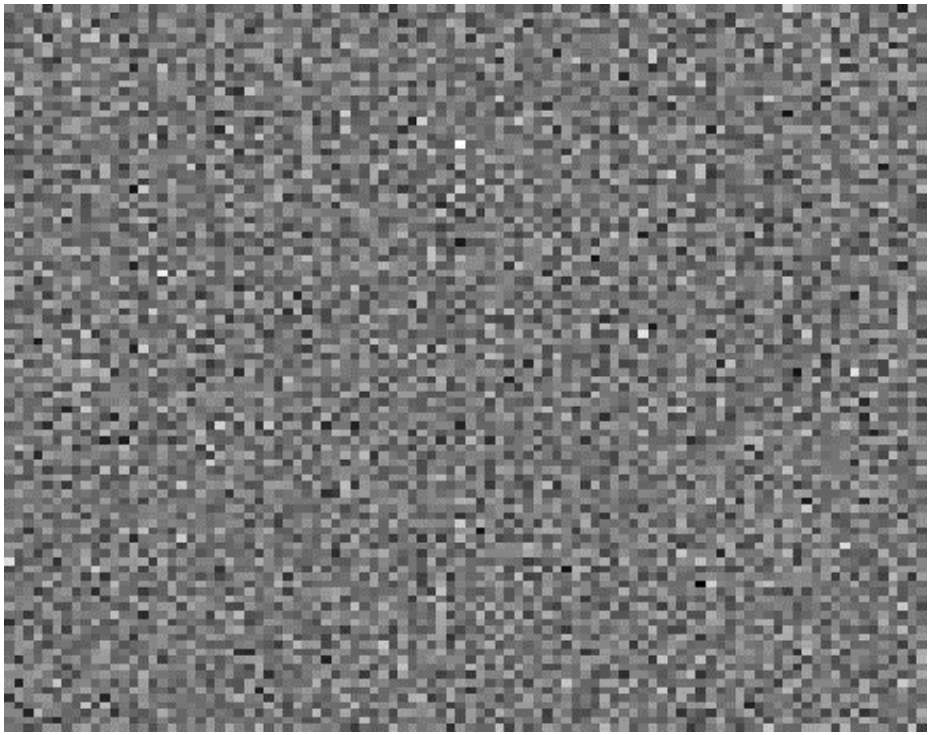
Vicarious calibrations are not significantly impacted by MTFC ON or MTFC OFF

SNR MTFC ON/MTFC OFF Imagery

NIR Kernel Applied to Simulated Imagery

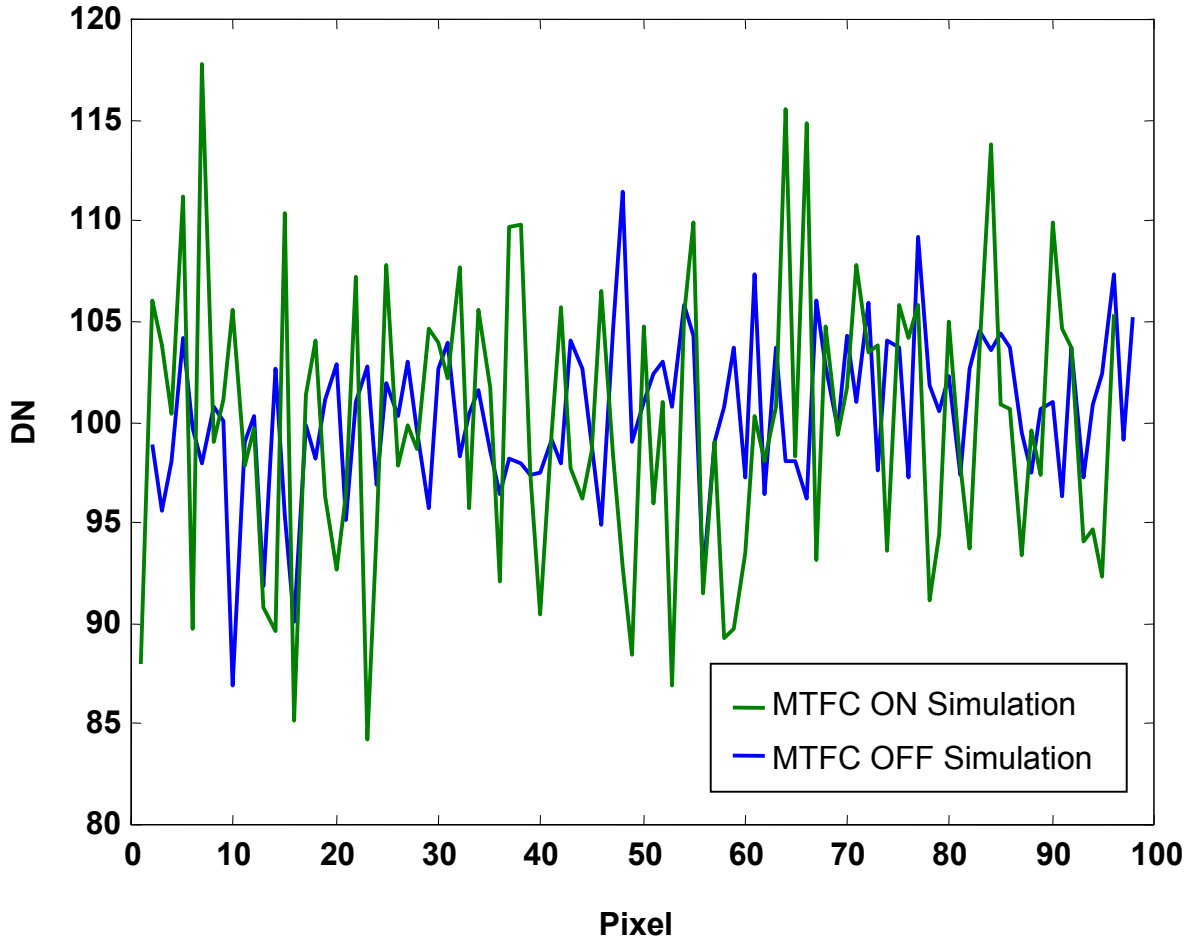


MTFC OFF SNR 25



MTFC ON SNR 13

Intercomparison



Summary

- **Significant radiometric differences between MTFC ON and MTF OFF imagery occur for some pixels**
- **Panchromatic MTFC much stronger than MS**
- **MS MTFC increases with increasing wavelength**
- **MS MTFC stronger in row direction then in column direction**
- **Radiometry comparisons involving averaging of many pixels (L7, MODIS) will not be effected**
- **Simulations indicate SNR for MTFC ON is less than MTFC OFF imagery (~50% for NIR Band)**